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DESIRABLE PRODUCT FROM THE TEACHER OF MATHEMATICS—THE POINT OF VIEW OF AN ENGINEERING TEACHER.[1]

THE school curriculum of to-day lies under the charge, vigorously pressed at the hands of many, of leaning to fads and being given over to poor teaching. The teaching of only two subjects seems to be excepted from the general charge of incompetency that is often made—namely, Latin and mathematics—and I have sometimes reflected upon the meaning and propriety of the exceptions. Returning to these reflections when your courteous secretary invited me to address you, I determined to lead you over some of this ground—old and often trod ground you may say—but nevertheless it is ground well worthy of surveying again and even again.

I think the charge of fads grows partly or wholly out of the character of work done in the kindergartens—under which name numerous sins are often cloaked by well meaning, accomplished, but highly impractical, and often incompetent, teachers. I am an earnest believer in the purposes of the kindergarten, but the practical results of its operation, where I have observed it, seem often to disseminate faulty methods of observation, poor workmanship in handicrafts and inaccuracy in thought. It is suggested that the pure kindergarten methods have their most important place in connection with the schools of social set-

[1] An address delivered before the general session of the Central Association of Science and Mathematics Teachers, November 25, 1904.

tlements and their like, which are found in the most densely settled portions of cities, and which have to do with children who find little or none of the gentle or softening influences of the average American home. These methods certainly bring a minimum of good to children of whom reasonable obedience and courteous bearing are expected in their home life.

To the kindergarten belongs the initial work of manual training. By that often abused phrase I particularly mean geometrical drawing and instruction in handicrafts of various kinds. Indeed, a relatively large proportion of the kindergarten pupil's time ought to be engrossed by manual training, because the brain is then specially amenable to training in the precise control of the senses; and this manual training ought to be carried up through the grades in the elementary schools with gradually decreasing allotment of time until it is nearly (or even entirely) succeeded by purely mental studies when the high school is reached. All that is now done with manual training in the high schools can be better done in the lower schools. But brains can be as easily produced by wishing, as precision of thought and act can be produced by an untrained teacher.

There is the rub in the situation. Poorly taught manual training is particularly dangerous because it encourages lack of precision in perception, performance and judgment, at the very time in his development when the habit of slovenly inaccuracy is most readily impressed upon the pupil. Less harm from poor teaching in this branch results in the high school than in the kindergarten, because the older child is less readily and less permanently affected by slovenly processes, if he has previously been under wise instruction. Also, better teachers, with reasonably good training, are available for the high school teaching of manual training, because better wages are there afforded. How can we expect—who should expect—accuracy of observation, precision of act and accuracy of thought to be inculcated in small children by a young woman who possesses not one of those important attributes herself, and who has never learned that they are important —indeed, essential—to the highest success in man or woman?

Gentlemen of the secondary schools, if you will lend your attention judiciously to reforming the schools below yours, and will really produce the reformation, you will be relieved of that disconcerting and mischievous pressure that is now directed towards securing for manual training a considerable portion of the time of the secondary school curriculum which is now occupied by what are commonly called disciplinary studies.

A few of the better universities acknowledge that a small amount of manual training is appropriate to the list of entrance requirements, and such an acknowledgment is quite usual by the engineering colleges (the University of Wisconsin admits not to exceed one unit out of the fourteen units of high school work accepted for entrance into engineering courses). Such a proportion is substantially as much as ought to be made a part of the high school curriculum, but it ought to be only the final capping of a stout pyramid of drawing and handicrafts which has its capacious lower leaf in the primary school or kindergarten. In this connection, let me say that much confusion exists in the minds of many regarding the relations of trades schools to high schools and of trades schools to university courses in engineering. Each of these has its own place, and they should not be confused.

Precision of observation, accuracy of execution and clear reasoning are necessary

to the best endeavor in all disciplinary studies, but particularly in mathematics. These attributes may be built up with peculiar success when the aid of rightly conceived and *wisely taught* manual training is invoked during the tender years of the pupil. But even when these attributes are possessed by all of your pupils, the fullest success in teaching mathematics will still demand a fixed purpose and high pedagogical ideals in the teacher, added to a sympathetic knowledge of his subject.

A *man* is a creature who honestly brings his undertakings to accurate results, even though the method adopted may not be the simplest or the one approved by academic authority. This requires an open mind, keen observation, analytical thinking and accurate powers of inference.

A parrot might glibly recite the rules for following an approved method, and then defend inaccurate results by the plea of carelessness, or haste in the particular instance.

The *man* may not know the rules as they are phrased in the books, but an inaccurate result is (for him) a matter of real chagrin and humiliation.

As the pupils now come to the colleges (perhaps I should refer more particularly to engineering colleges, as with them my experience more particularly lies) from the secondary schools, they ordinarily possess little power of clear thinking, power of initiative, regard for accuracy, or understanding of continuous intellectual effort. It is true that they are not yet mature in either body or mind, and too much should not be expected of them. But it is also true that their preparatory schooling has left them with a defective acquaintance with the construction of the English language and the spelling of English words, a still more defective acquaintance with French or German or a fairly good grounding in elementary Latin, a smattering of civics and history, a training in the elementary principles of arithmetic, geometry and algebra, *from which the factor of accuracy in application has often been omitted,* and perhaps an enthusiastic though often misguided interest in the physical sciences.

I do not wish you to think of me as reflecting on the industry of the secondary school teachers. The facts are as I have stated them, but I can truthfully say that, considering all of the conditions, there is probably no more painstaking and right wishing body of people than these teachers. It is the conditions that are not right. The schools encourage, as Herbert Spencer says, '*submissive receptivity* instead of *independent activity.*' The unfortunate situation is, perhaps, a result of the inexperience of school boards, or the inexperience, inadequate compensation or improper training of a large proportion of the teachers, or the crowding of the schools may overwork and cramp the best of teachers.

Many of the faults in the secondary school training (which has been the lot of students entering our engineering colleges) may be caused by a doubt that has recently seemed to unsettle certain educational circles on account of the question whether high schools shall be the 'people's colleges,' or remain in the station of secondary schools. This doubt is apparently not yet resolved in the minds of those who undertake to mold educational thought in the secondary schools; but the traditional old time secondary school training which produced men who could spell and cipher and who had received a thorough and accurate drill in at least one language is certainly to be given foremost place as a preparation for a college course. In my estimation, when accompanied with history and a year spent in civics and natural sci-

ence, it is not only an advantageous school course for preparing students for college, but it is a preferable course for those numerous young people who can not go through college.

Many of the errors of teaching in the universities are the result of an undiscriminating chasing after the popular cry, and many spurious pedagogical ideas are still propagated which were long since laid by the competent leaders. I presume that the same condition is found in the secondary schools. What engineering teacher can do his duty who does not understand the truly simple relation between theory and practice, and where can he find it better expressed than when reading the inaugural dissertation of Professor Rankine? What secondary school teacher can teach his best, whatever may be his instinctive capacity, who has not read Montaigne's essays on teaching or Spencer's little book on education, or who has not absorbed the point of view of some of the great teachers through adequate biographies?

Of the elementary mathematics taught in the schools, I have just said that the factor of accuracy in application is often omitted, or, if it is not actually omitted, it is largely neglected.

Contact with men entering college shows that:

The arithmetic class is taught the rules, but not the reasoning upon which the rules are founded or the overshadowing importance of impeccable accuracy in numerical results.

The algebra class is taught to transform (or, as I may call it, juggle) equations, but little thought is bestowed where the greatest thought belongs—that is, to the physical meaning of each form that is produced. This fault, I must admit, is not missing from the universities, and is propagated in the schools by association.

The geometry class is apparently taught by rote, and even where a show is made of encouraging the originality of the pupils it is likely to be more an illusion than a fact.

Large classes encourage teaching for the average mass, rather than the stirring of each individual as must be done to create the fullest results. Apparently in few mathematics classes are the pupils taught to scrutinize and check the results of their labors by means appealing more to the common sense than to cut and dried methods. Many years of observation with college students have shown me that the attention of secondary school pupils is seldom drawn to such useful processes for checking numerical results (which were taught with fidelity to our fathers) as 'casting out the nines'; and the worst of it is that the pupils have not been taught even the simple philosophy of our decimal system which might enable them to work out the processes for themselves.

If the causes that contribute to allow the pupils to reach the end of the secondary school training with their originality sleeping, their normal sense of accuracy lost and their best accomplishment in mathematics a parrot-like following of hackneyed method in familiar problems—if the causes from which these conditions spring are anchored in overcrowded classes, then it is your duty and privilege to cry aloud for more air, more breath of life, more chance to teach each living individual instead of the average of an inert class.

Mathematics is a tool—a powerful system of logic, an aid to reasoning—which confers power and advantage on the individual in proportion to the fullness of his possession. The value of mental discipline obtained while accomplishing that possession is inestimable. And the teacher's aim ought to be to make that possession most

complete in those respects which stimulate the powers of accurate (straight) reasoning.

It has seemed to me that the present teaching of mathematics is not so effective as that brought to bear on my generation in the secondary schools, and it likewise appears to me that my generation was less effectively taught to reason, through mathematics, than was my father and his generation.

I am not a reactionary or one who exalts the past above the present. But I see a reason for the present condition in the extended introduction of analytical mathematics and a consequent relegation of constructive mathematics to a minor place. The introduction of the analytical mathematics is not of itself to be regretted, but it seems to have brought with it a change in the method of teaching which is profoundly unfortunate. The teacher now feels under requirement to lead a large class over certain ground in a given time, and (to use the concrete example of algebra) he finds he may do so by expecting the students to learn the processes by the book, and solve the equations, but he has no time (nor strength, if the class is unduly large) to spend in the work which is really of overshadowing importance—that is, drilling the students to interpret the physical meaning of each pregnant transformation.

Unhappily this condition has had the support of the science departments (especially of mathematics and physics) in some of our great universities, where it has been held that the equation is the thing and the interpretation of minor moment; and with this support in high quarters, how should we expect the stupefying mechanical method to be banished from the secondary schools.

But, gentlemen, *the equation is not the thing*. The interpretation of the equation —an understanding of the real meaning of transformations, and a grasp of the relations of things, which lead to sound reasoning—is the feature of first importance to be derived from the study of mathematics.

The mental subsoil is stirred in developing physical conceptions of the relations of things, while even the sod may not be well broken in learning the processes of juggling equations. Stirring the mental depths often calls for the exertion of the utmost powers of good teaching, but poor teaching is inexcusable, unless, much easier as it is, it may be exacted by the undermanned and overcrowded conditions of some of our schools.

What constitute first-rate instincts in a teacher of mathematics may be illustrated by an anecdote:

Some years ago a mature graduate student who was in one of my college classes asked me if it would not be better to go slower at some places so that the class should *thoroughly understand the relations of things*, even if we did not cover the whole subject in the allotted time. This was text-book work and in an engineering subject of analytical character. We were then covering only ten or twelve duodecimo pages per day, but the book was one in which nearly every sentence was charged with important meaning and each mathematical expression, however simple or complicated, represented some important physical relations.

The student had been a college instructor with a fine reputation as a teacher of mathematics or mechanics, and since then he has become a professor of engineering. I have understood that he has strongly entrenched his reputation as a man whose students become young men of discreet thought, notable for resourcefulness and character.

What we need from the mathematics teacher is, not for them to produce young men who can juggle equations, but to produce young men who can recognize the relations of things.

My limit of time is presumably exhausted, and I will conclude. You probably will not all now agree with my opinions, but fair opinions honestly spoken ought to offend no one; and I am satisfied that my opinions will be sustained in the minds of the majority of experienced teachers in engineering colleges who have given careful thought to the question before us. When the University of Wisconsin puts into effect a year hence its promulgated additional requirements in algebra preparation for students entering the college of engineering, it is not so much because we particularly care for more pages of the book to be covered in the high schools, but because we hope that the students (with more time allotted to the subject) may attain more of the true powers of reasoning that come from searching for and recognizing the relations of things.

If a teacher's pupils are capable of transforming (juggling) equations correctly according to rule, without giving a thought to the meaning of the forms produced, or are capable of following through an arithmetical problem by the approved method without considering the reasonable accuracy of the numerical results, then that teacher's sowing has been choked with tares. But a teacher of mathematics who leads his pupils to give due thought in the course of their work to interpreting equations, to noticing the relations of things, and to scrutinizing and checking the accuracy of every numerical result (even though the pupils may evolve, for their own use, awkward and unapproved analytical methods)—that teacher's sowing is of golden wheat.

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THEORIES OF METABOLISM.[1]

The sum of the chemical changes which take place within the organism under the influence of living cells is called metabolism. This paper is to discuss the character of these changes and to consider, as far as we may, their cause.

It was Lavoisier who first understood that oxygen supported combustion and he compared life with the flame of a candle. He conceived the idea that hydrogen and carbon were brought to the lungs by the blood and there united with oxygen. It was, however, observed that the heat production was not confined to the lungs, and when Magnus found that venous blood was richer in carbon dioxide and poorer in oxygen than was arterial blood, the process of oxidation was placed in the blood. Ludwig in his later years believed this. The prevailing view, however, is that the processes of metabolism take place within the cells of the body.

Lavoisier believed that oxygen was the cause of the metabolism. Liebig thought that fat and carbohydrates were destroyed by oxygen, while proteid metabolism took place on account of muscle work. Voit showed that muscle work did not increase proteid metabolism and that the metabolism was not proportional to the oxygen supply. The amount of oxygen absorbed apparently depended upon what metabolized in the cells. He showed that although fat burned readily in the air, it burned only with great difficulty in the body; and that proteid burned with comparative difficulty in the air, but went to pieces very readily in the body. Voit believed that the cause

[1] A paper read before the New York Section of the American Chemical Society.